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ESTIMATION OF RIVER FLOW AND IMPROVEMENT OF DATA COLLECTION

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ESTIMATION OF RIVER FLOW AND IMPROVEMENT OF DATA COLLECTION

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Introduction:

1. Turkey has a very wide range of climatic variations and thus deserves the name of Asia Minor, having all the features of a small continent. The average annual precipitation ranges from 200 mm. in the central plateau of Anatolia, to 3000 mm. in the Eastern Black Sea coastal region. On the mediterranean coast the growing season covers the whole year in contrast with the North-Eastern plateau of Kars where the growing-season is only four months.

2. The wide seasonal, yearly and area variations of climatic factors poses a variety of problems to engineers who deal with projects of irrigation, power and flood control. The estimation of river flow is one of these problems and the lack of reliable long-term records makes this task especially difficult.

A. General review of hydrometrical and meteorological network in Turkey.

a) History:

3. The systematic data collection in the field of meteorology in Turkey was begun about thirty-five years ago, when the young Turkish Republic established base meteorological stations in the principal cities of Turkey. River gauging began (with ten years of delay) in the middle of the 1930-1940 decade. Figure 1 shows the rate of increase on the number of meteorological and hydrometrical stations. The rate has been relatively rapid in the last few years, as engineers became aware of the importance of the meteorological and hydrological studies for the project investigations and project design.

b) Statistics:

4. Turkey has now 750 meteorological stations in operation 150 base stations are equipped with instruments measuring precipitation, temperature, atmospheric humidity, wind velocity, solar radiation and evaporation, 120 stations with recording precipitation gauges. The remaining 630 stations measure only the precipitation on a daily basis. Compared to the total land area of the country, there is about one station in 1000 km^2, the density being some what higher in

Western Turkey. The immediate goal should be to double this figure in five years to reach a satisfactory network density.

5. The meteorological stations in Turkey are established and operated by different agencies of the government. The main agency which is responsible for meteorological data-collecting is the Directorate of Meteorology, which operates about 650 stations, most of the other stations being operated by the State Hydraulic Works. This duplication is regrettable, but attempts are being made to unify the network.

6. The hydrometrical network consist of about 650 stream-gauging stations. This figure would be satisfactory if only good rating curves were available for all of them. At the present state about 150 stream-gauging stations have records of discharge, the others having only some discharge measurements and records of stages.

7. The hydrometrical network is operated by the Directorate of Hydro-Power Department and the State Hydraulic Works which have almost equal number of stream-gauging stations in operation. The same duplication unfortunately exists as for meteorological network but we are confident that in the near future stream-gauging network will be operated by a unique agency of the government.

8. As the needs of the country increase for natural resources development the data collecting work will have its right place among the other activities of the nation. It can be said rightly that the degree of civilization of a country is directly proportional to the measurements made in its borders.

B. Methods of River Flow Estimation:

a) Where long-term records are available.

9. It is unnecessary to say that where long-term records exist, there is but little difficulty left to hydrologist. However it should be stressed that even with fairly long records, problems of river flow estimation arise, as it was shown by Hurst in the study of the Nile Basin.

10. The two important estimates hydrologist has to make are the mean and the variation of the river flow. It is known that the reliability of a mean (the inverse of its standard error) is proportional to the square root of the number of observations for random events. But for natural phenomena as precipitation and river flow, this reliability grows slower than the square-root of the number of years of record as it was shown by several eminent hydrologists. This is why there is always interest to try to lengthen the records by correlation using precipitation and limnological records which generally cover longer periods of time.

11. The daily, seasonal and yearly variation of the river flow is another important factor in the hydrological studies. The design of the projects which use the natural flow of the rivers or stored water requires a good knowledge of this variation. The probability considerations which are formulated in the frequency analysis are of utmost importance. We like to state that the hypothesis which lies at the bottom of the so-called operation studies made using the actual records, is simply the exact reproduction of past records in the future. It is seen that this hypothesis do not have a logical basis. Efforts should be made in order to determine the most probable sequences of years which will occur in the future. Past records may contain some rare sequences of years to be eliminated by probability considerations. As we are confident that the probability of having head, while tossing a coin, even after ten heads are seen consecutively, is exactly 1/2 for the next throw, the hydrologist should try to understand the laws of probability which govern the stream flow, rather than use past records directly.

12. The determination of capacities for reservoirs is made taking into consideration the probability of the critical periods to be used in the operation studies. The solution of the problem is rather obvious in the case of the critical periods shorter than one year. A frequency analysis can be made in this case in order to determine a critical period with a given period of return. The problem becomes difficult with critical periods longer than one year, and the efforts to find a satisfactory solution to this problem was unfruitful.

13. It is unnecessary to say that these studies should be made on a basin-wide scale. Dimensionless capacity-draft curves are developed for several long-term stations and the mean of these curves is used to estimate the capacity required to regulate the stream flow. This curve may be used advantageously for the basins where there are only short-term records or no records at all.

14. Our experience in Turkey proved that the economical capacities of reservoirs generally lies between the average yearly flow volume and the half of this volume. Smaller reservoirs have problems due to the sedimentation and the bigger ones do not have economic justification.

b) Where only short-term records are available:

15. The correlation technique is extensively used in the hydrological studies in Turkey. The application of this technique, we like to stress, requires a good knowledge of statistics and the hydrological characteristics of the basins under consideration. Flow versus flow correlations are most generally used on a monthly basis and the relation proved to be generally linear. For rivers fed by the snow melt corrections are made where the flows are desynchronised by the effect of difference in altitudes. For the precipitation versus flow correlations it was found not that the non-growing season precipitation was the most significant variable to estimate the total yearly flow volume and again linear relations are most generally found, a fact that does not agree with theoretical considerations. In basins where the snow-melt is the dominant factor for the river flow the regression equations may be used to forecast the seasonal runoff, the winder precipitation, in this case, having a close relation with the water-content of the snow-pack before the melting season.

c) Where there are only spot measurements of discharge:

16. It is rather difficult to attempt a correlation analysis where only spot measurements of discharge exist. But if the station is not very far from a station with long term records satisfactory results are obtained. Figure II - shows such a correlation. If the spot measurements do not cover an important range of the stream-flow this technique may lead to misleading results, the relation for different rates of discharge being not the same.

17. Some times when only discharge measurements for minimum flows are available it is possible to make an estimate of the average flow by using the ratio of the mean minimum flow to mean flow. This ratio does not change much for large basins. For example for the Eastern regions the mean minimum flow is approximately one third of the mean flow.

18. The variability of the daily flows are estimated from the dimensionless discharge - duration curves developed using the records of the long-term stations. For this study log probability scale is used.

d)Where no records are available:

19. If the density of stream gauging stations is relatively high it is possible to estimate the runoff from an ungauged area by comparing the hydrological characteristics of this latter with the other gauged areas. In this study the precipitation records are of valuable help to hydrologists. The fundamental hydrologic equation, that is the relation Precipitation=Runoff + (Evapo-transpiration) is advantageously used. Evapo-transpiration may be estimated by analysing the data available for the gauged areas.

20. The other factors as geology, soil and vegetation cover the slope of the basin should be taken into consideration to reach a reasonable estimate of the runoff for the ungauged areas.

e) Critical review of methods of river flow estimation:

21. In the river flow estimation problem, as it is seen in the previous paragraphs, the most important factors are the reliability and the length of the records. But the extension and the interpretation of the records by using statistical techniques and basin wide studies also should be emphasised.

22. This is especially important for countries such as Turkey which do not have adequate records for hydrological studies. A good understanding of the probability and the regression theory is essential. There is no time to wait to obtain long-term records and unfortunately little help from the foreign experience. We welcome any method or suggestion which could help us in the improvement of hydrological studies made with short-term records or in the basins where no record is available.

C. Estimation of extremes of stream-flow:

a) Flood flows.

23. The estimation of flood flows present difficulties which do not exist for normal or minimum discharges. It is seldom possible to measure directly the high values of stream flow, the flood peaks for example, and a method of estimation is necessary. When a rating curve is available the logarithmic extension or Ad 1/2 method may be used. But there are cases where these methods fail, especially where the flood plain conveys a major part of the flood flow. The hydraulic characteristics of the gauging stations are an important factor for the extension of the rating curves. There is also an interesting chart developed by Langbein which gives good results to estimate the peak flood discharge. This chart uses the ratios of the mean daily discharges of preceeding and succeeding days to the mean flow of the day the maximum is observed. Figure III - shows the agreement of this method with the maximum discharges estimated from the rating curves.

b) Estimation of flood flows for the ungauged areas:

24. The estimation of flood flows for the basins where no records are available is made by using empirical formulae, developed by using the records of long-term stations. The general relation

$$\bar{Q}_{max} = CA^{2/3}$$

was found in a study made in a country-wide scale. In this formula $\bar{Q}_{max}$ is the yearly mean flood peak discharge in $m^3/Sec.$, A. the effective contributing drainage area in km^2, and C, a regional constant which varies between 1.0 and 5.0 for Turkish rivers. The variability of yearly floods are estimated from the records of long-term stations and an average coefficient of variation is applied to the ungauged areas. The method developed by Dalrymple is used for the basin wide studies. For the frequency analysis Gumbel's method is preferred to the methods which include a coefficient of skew.

c) Small basin subject to warm-season convective storms:

25. One of the most difficult problems in flood flow estimation are the small basins subject to warm-season convective storms. These storms cover an area of about 500 km^2 and gives exceptionably high flood peaks. The duration is in the order of several hours and it is impossible to estimate the discharge by using the rating curves or direct measurements. The use of slope-area method is necessarily imposed.

26. The use of crest-staff gauges has just begun in Turkey and the establishment of 100 gauges in the next year is planned. We hope that in this way we will obtain interesting results in the small watersheds by using the slope-area method.

27. It is also difficult to make a frequency analysis for this type of flood. When such a storm hits a basin one should wait another five years to experience another similar phenomenon. The yearly-flood method is inadequate to handle this problem. If we had a long-term record - 100 years for example - we could very well study these floods on a five-year basins and have about 20 points to plot on the probability-paper. The work continues to estimate this type of flood using the precipitation records and combining the records of several

stations (ergotic hypothesis).

d) Estimation of spillway design floods:

28. The estimation of spillway design floods is made using envelope curves for the most critical floods experienced in the past. This method is, of course, a very rough one but we believe that with a careful study of the basin it is possible for an experienced engineer to make a reasonable estimate. The frequency methods are especially avoided in these estimates. The unit-hydrograph method is naturally better to solve this problem, but our attempts did not reach satisfactory results, due to the lack of adequate precipitation and stream-flow records.

e) Estimation of minimum flows:

29. As for the flood flows the estimation of minimum flows is generally made by an extension of the rating curve. To avoid this, it is desirable to make direct measurements for minimum discharges This is not a difficult problem, because the duration of low stages are much longer than the high stages.

30. A fact which is generally overlooked when the site of a gauging station selected is the so-called sensibility of the station. As it can be seen easily the sensibility of a station is directly proportional to the roughness of the river bed and inversely proportional to the width of the river bed and the water surface gradient. There is always interest to select sites with good hydraulic characteristics to have a sensible stage-discharge relation and this is especially important in the case of minimum flows.

D. Importance of adequate data collection and improvement of methods of estimation.

a) Base Stations:

31. Time sampling is made by the base stations. There are about 100 base gauging stations in operation in Turkey. These stations are established mostly in large basins and are equipped or being equipped by automatic recording instruments.

b) Secondary stations:

32. These stations are established to make the area-sampling and following the requirement of the projects under consideration. They are generally equipped with simple staff gauges, and some are being equipped with crest-staff gauges.

33. The establishment of experimental watersheds has just begun in Turkey. Such basins are equipped with a dense network of precipitation gauges and a base meteorological station with a gauging station equipped with automatic recorder.

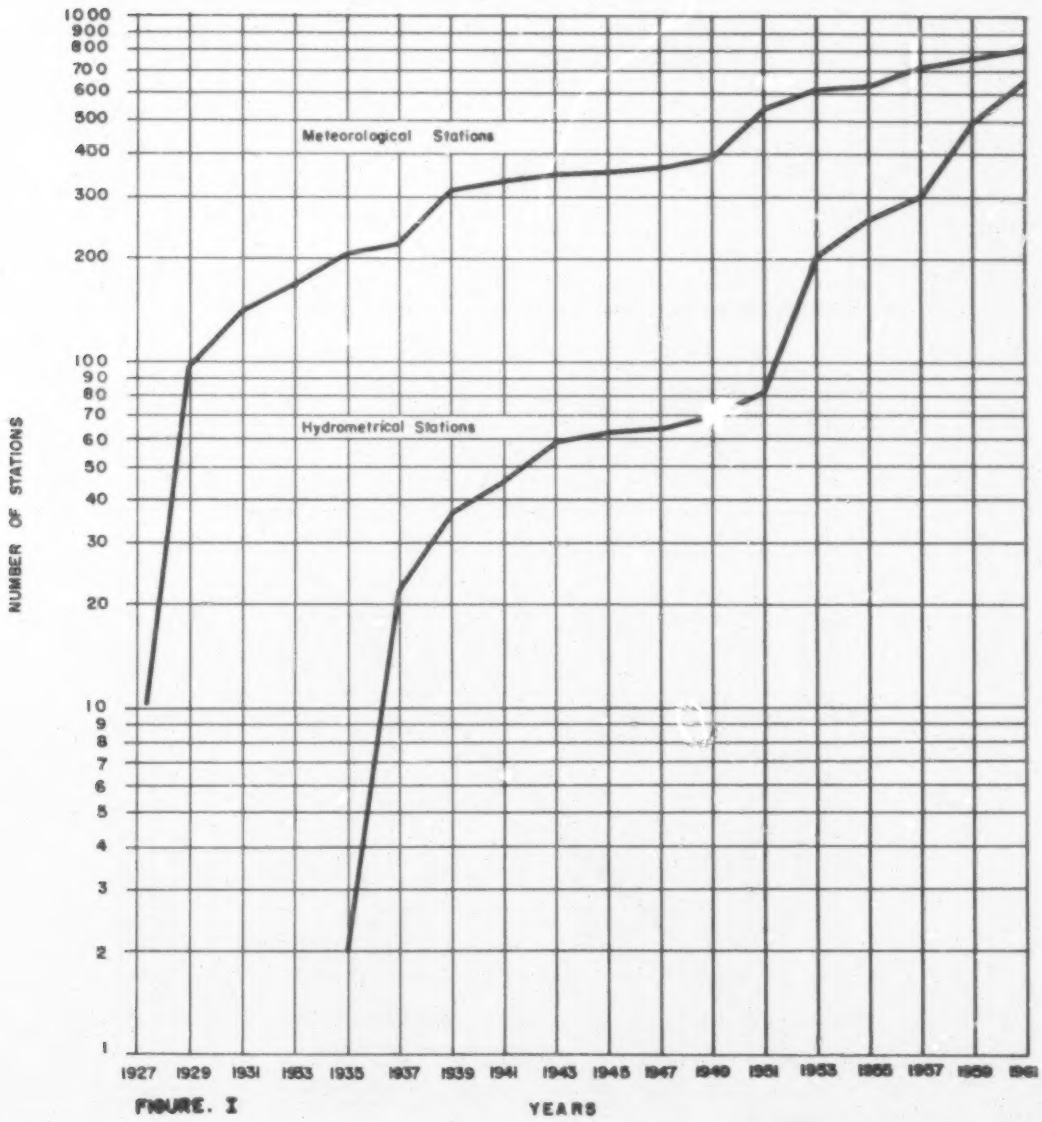

FIGURE. I

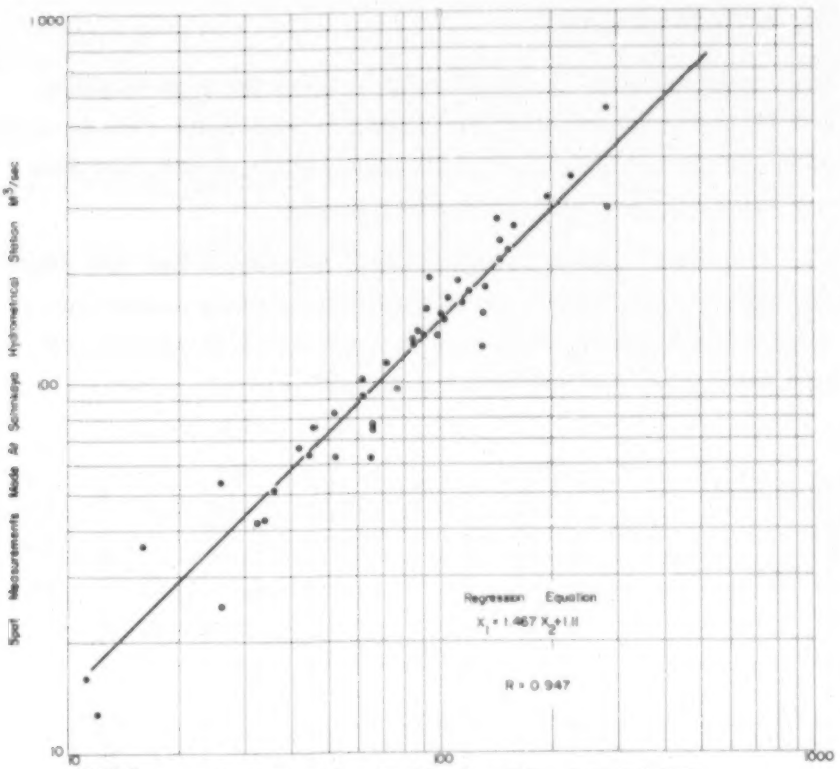

FIGURE . II Daily Discharges Obtained From The Rating Curve At Kanp Hydrometrical Station

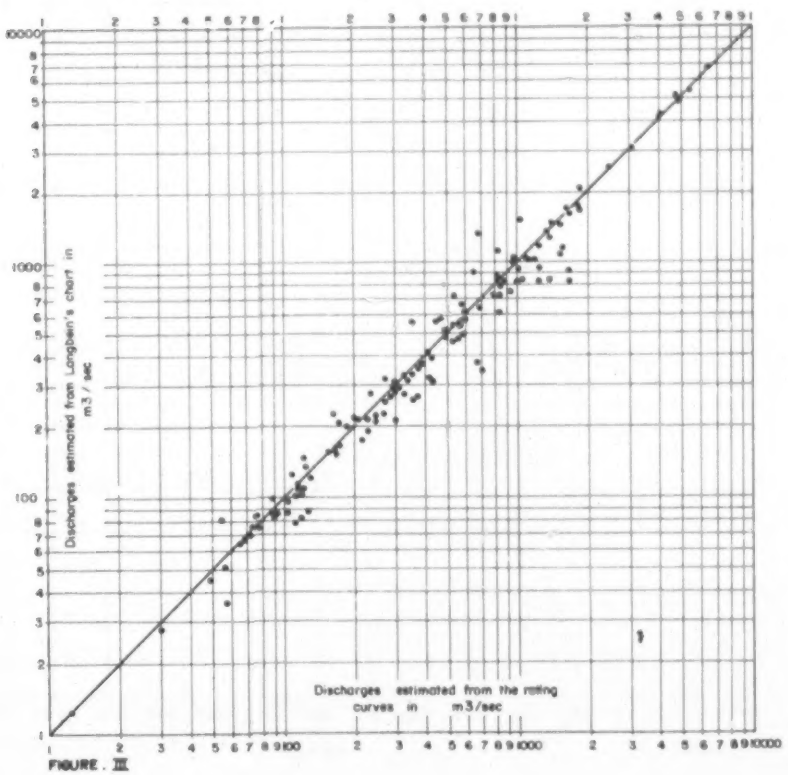

FIGURE . III

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